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COVER SHEET FOR TECHNICAL MEMORANDUM

TITLE- Apollo Prelaunch Cabin Atmosphere - A Summary of Requirements and Constraints, Options and Trade-Offs

TM- 67-2031-5

DATE- September 30, 1967

FILING CASE NO(S)- 330

AUTHOR(S)- P.F. Sennewald

FILING SUBJECT(S)- (ASSIGNED BY AUTHOR(S)-
Prelaunch Atmosphere Selection
"Air-on-the-Pad"
Fire Risk
Crew Safety

ABSTRACT

The results and conclusions of several studies concerning Apollo prelaunch cabin atmosphere constraints, requirements and capabilities are summarized. Particular attention is directed to the air-on-the-pad option being provided in the Command Module. Physiological and other environmental requirements and constraints are related to several risk regimes in the Apollo prelaunch and launch phases. Some relative comparisons are made of fire and of physiological risks in these regimes and the merits evaluated for the several options available within both existing and modified spacecraft capabilities to manage unacceptable risks.

Assuming that provision of independent primary and backup capabilities is a valid program objective -- e.g., the space suit as a backup to the cabin during shirtsleeve operations -- this summary shows:

1. The dominant atmosphere-dependent crew risks do not occur in the prelaunch period, but are encountered during the S-IC burn for the nominal mission and during aborts from the S-II and S-IVB burns. This risk is predominantly fire related during S-IC burn and physiologically related during aborts from S-II and S-IVB burns.

2. The present plans for implementation of both the pure oxygen and the air options for cabin atmosphere do not insure accessibility of an independent backup atmosphere to the suit circuit during the high stress portions of a nominal launch and during launch aborts.

   The current provision for direct oxygen purge of the space suit through the suit loop does not insure an independent backup atmosphere since it is susceptible to failure modes common to the suit loop.

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Abstract

Access to the cabin atmosphere for use as a backup atmosphere is inhibited by the launch environment and the space suit design - i.e., the bubble helmet - and the cabin acoustical environment may be unacceptable. For an air cabin atmosphere, enrichment to a viable level during launch is not consistent with use of air-on-the-pad to reduce fire risk.

3. An alternate backup atmosphere of pure oxygen supplied directly to the suited crewmen is required for both air-on-the-pad and oxygen-on-the-pad capabilities. Further, such a supply could also serve as a backup during any cabin depressurization procedures required to exchange cabin atmospheres.

4. The most relevant determinant regarding use of the oxygen or air option is the trade-off between fire and physiological risks. Fire risk definition, currently dependent on materials selection and flammability tests, must consider the simultaneous effects between 50 and 120 seconds after lift-off of:

   (a) the maximum launch environment, and

   (b) the decline in spacecraft pressures from pad to flight levels and the associated turbulence of the cabin atmosphere.

   It is not possible to determine which of these effects is predominant at this time.

5. The effects of arterial blood desaturation on crew performance due to acceleration loads, in particular during aborts, support a requirement for pure oxygen in the backup atmosphere. These effects need to be better defined with additional physiological data and tests.

Based on these findings, it is recommended:

1. An Alternate Oxygen Supply independent of the suit loop and cabin atmospheres be implemented to supply a backup atmosphere directly to the suited crew during prelaunch, launch and flight.

2. Additional gaseous oxygen tanks be incorporated <u>if</u> rapid conversion of an air cabin atmosphere to pure oxygen without cabin depressurization is required.

3. Data on the physiological effects of acceleration loads on atmospheric requirements be better defined.

Abstract

4. The materials selection program review the need for flammability data during the simultaneous occurrence of maximum launch environments and decreasing cabin atmospheric pressures.

Finally, it is suggested that since a period of high fire risk occurs after lift-off, implementation of an Alternate Oxygen Supply would permit inerting of the cabin atmosphere as required to further reduce fire risk both before and after lift-off. Such a risk reduction would also decrease the reliance on rapid crew egress and the quick opening hatch on the pad.

BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Apollo Prelaunch Cabin Atmosphere - A Summary of Requirements and Constraints, Options and Trade-Offs - Case 330

DATE: September 30, 1967

FROM: P. F. Sennewald

TM- 67-2031-5

TECHNICAL MEMORANDUM

1.0 INTRODUCTION

This memorandum first states the pertinent physiological requirements and the resultant constraints for the primary and backup atmospheres for the prelaunch and launch phases. These phases are then divided into risk regimes and two conflicting elements of the overall risk--fire and physiological--are reviewed. Finally, the merits of implementing those alternatives which meet the requirements and constraints and minimize crew risk are assessed.

Pure oxygen at a pressure of 5 psia will be used as the atmosphere in the Apollo Command Module cabin during space flight. Studies* continue to indicate that this atmosphere will provide the highest overall crew safety in-flight from the standpoint of fire hazard, physiological risks, and system reliability. The Apollo program is providing the option of using a pure oxygen cabin atmosphere (as in Mercury and Gemini) or launching with an air cabin atmosphere** and subsequently changing to a pure oxygen in-flight atmosphere. The option which leads to the lowest overall crew risk should be chosen; therefore, the objective of this paper is to identify the atmosphere dependent risks and changes required to manage these risks.

This summary is based on the results and conclusions of other studies*** which include physiological requirements, operational considerations, current status of spacecraft design, and design changes possible in the spacecraft. In addition it includes some considerations related to fire hazards.

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*Reference 1

**Early in Mercury, air was considered for the cabin during prelaunch; however, adverse experience in keeping the nitrogen component out of the primary crew breathing (suit loop) atmosphere and weight limitations resulted in the use of pure oxygen.

***References 1, 2, 3, 4, 5 and 6.

2.0 APOLLO PROGRAM REQUIREMENTS

Crew safety is a primary consideration in the design of the Apollo system and is defined in the Apollo Program Specification as "the safe return of all crew members whether or not a mission is completed." Further, "...no single failure shall cause the loss of any crew member, prevent the successful continuation of the mission, or in the event of a second failure in the same area, prevent a successful abort of the mission."

To meet these objectives, the Apollo spacecraft must have both primary and independent backup capabilities which meet the physiological requirements for both the composition and pressure of a viable atmosphere. Two atmosphere control capabilities are provided in the Apollo spacecraft, the cabin atmosphere system (or cabin) and the pressure garment system (or suit loop). These two capabilities are not completely independent since some atmosphere control functions are used in both systems; for example, the gas flow and carbon dioxide removal functions are common to both. As a result, the components providing these functions (compressors and lithium hydroxide cannisters) are redundant.

In general, the roles of the suit loop and cabin systems as primary and backup atmospheres are interchangeable during a mission depending upon crew safety requirements. During periods of coasting flight, the cabin atmosphere will be primary, allowing shirtsleeve operations, and the suit loop will be the backup. During powered flight the space suits will be fully donned (including the bubble helmets) enabling the suit loop (including redundant modes) to be the primary atmosphere with the cabin as the backup.

3.0 PHYSIOLOGICAL REQUIREMENTS AND ATMOSPHERIC CONSTRAINTS

The pertinent basic physiological concerns related to atmosphere are hypoxia (insufficient oxygen), dysbarism (decompression sickness), oxygen toxicity and oxygen desaturation of the arterial blood (due to acceleration loads on the crew). These are discussed in detail in References 1 and 2; the resultant constraints are summarized for the primary and backup atmospheres in this section. Since the current primary atmosphere of pure oxygen most nearly satisfies requirements based on these concerns, the backup atmosphere constraints are discussed in more detail.

3.1 Atmospheric Requirements and Constraints

Avoidance of hypoxia during the prelaunch and launch phase requires as a minimum the partial pressure of oxygen profile shown in Figure 1 as a function of Saturn V launch pressure profiles. These minimums are based on sea level equivalent performance capabilities--i.e., without consideration of additive effects due to any other environmental stresses.

Dysbarism effects--the release of absorbed nitrogen within the body during pressure reductions--can be controlled by eliminating nitrogen from the crew during the prelaunch period. This "denitrogenation" requires the use of 100% oxygen in at least the primary atmosphere--the suit loop--for several hours preceeding the launch phase pressure reduction. The use of pure oxygen as the backup atmosphere during prelaunch to avoid dysbarism effects is not a firm physiological requirement. However, pure oxygen in the crew compartment would minimize the chance of suit loop contamination with nitrogen and would increase operational flexibility and reliability. Pure oxygen in the cabin also increases the fire risk.

Oxygen toxicity effects, due to exposure to pure oxygen at atmospheric pressures, impose a maximum crew exposure limit of about six hours. The anticipated exposure time is about three hours which provides a margin of only three hours for holds.

The physiological effects of acceleration loads on the crew can be minimized by the use of pure oxygen for the primary and for the backup atmospheres prior to, during and after onset of the loads. The backup atmosphere requirement for pure oxygen is based on the possibility that a failure may occur in the primary atmosphere. Pure oxygen at pressures higher than permitted by the current spacecraft design would offer further alleviation of the effects of g-loads; however, further data is needed to support an increased requirement.

The resultant atmospheric constraints are shown in Figures 1 and 2 and are based on launch environments shown in Figure 3. In essence:

1. For the <u>primary atmosphere</u>, pure oxygen is required during the prelaunch and launch phase at the pressures permitted by current design to avoid dysbarism;

2. For the <u>backup atmosphere</u>, an "air" atmosphere, enriched to a sea level equivalent, is required as a minimum; when the nominal or abort g-loads can exceed about four g's, pure oxygen is required.

The significant point in (2) is the rapid rise in abort loads (to >>4g) for $T \geq 120$ seconds and their occurrence immediately after abort initiation for aborts at $T \approx 120$ seconds; therefore, pure oxygen is required for $T \geq 120$ seconds. For $T \geq 155$ seconds, the pure oxygen requirement can be made conditional since the entry g-loads do not occur immediately after abort initiation.* For $0 < T < 50$ seconds, abort with an air atmosphere

*As discussed in Reference 2.

is acceptable since the cabin pressure is still at sea level pressures. For 50 < T < 120 seconds, abort with an air atmosphere even at reduced pressures is feasible since acceleration loads are moderate and the time in flight is sufficiently short to avoid degrading effects. Thus, for T < 120 seconds air at sea level pressure or enriched to a sea level equivalent is adequate and for T $\geq$ 120 seconds pure oxygen is needed as the backup atmosphere.

4.0 OTHER ENVIRONMENTAL CONSIDERATIONS*

Space suit design and the acceleration, acoustical and vibration environments of the launch phase constrain the accessibility and utility of the cabin atmosphere as a backup. The nominal acceleration and vibration environments are most severe for 50 < T < 155 seconds and it will be difficult at best, and perhaps impossible, to remove the bubble helmet of the Apollo space suit to gain access to the cabin atmosphere for use as a backup. Still higher abort acceleration loads further reduce the accessibility during aborts. Since the bubble helmet affords a large amount of acoustical isolation--about 30 db--and since the cabin acoustical levels during launch may be high--design criteria are 123-127 db**--the resultant increase in noise due to helmet removal will degrade crew-to-crew and crew-to-ground communications and will increase the overall environmental stress on the crew.

As a result, the cabin atmosphere is judged essentially unavailable with the current hardware design for use as backup atmosphere for 50 < T < 155 seconds and possibly of marginal value due to acoustical levels--even if accessible--for the remainder of the launch phase.

5.0 EVALUATION OF OVERALL RISK

In order to better understand atmosphere dependent risks, it is useful to subdivide the prelaunch and launch phase into risk regimes. Six regimes have been defined by significant changes in environmental or other parameters.

Two major components of the overall risk are fire risk and physiological risk. As used here, these risks reflect the likelihood of occurrence of an event detrimental to the crew and

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*Based on References 2 and 3.

**Reference = 0.0002 dynes/cm^2.

the seriousness of the consequences, e.g., high ignition probability coupled with easy crew egress is considered a relatively low risk. For purposes of risk review, the lack of accessibility to the cabin atmosphere for use as a backup is considered separately and not included since provisions for access represent a similar problem for air or oxygen. It is assumed that the programs for ignition source removal and protection and for material selection have been reasonably effective in reducing but not eliminating fire risk.

5.1 Pad Access - Hatch Open Regime (-180 < T < -90 Minutes)

Both the fire and physiological risks in this regime can be considered as baseline risks since they are not affected by the use of oxygen or air as a cabin pressurant. This is a minimum fire risk regime due to the unimpeded egress, availability of pad support capabilities and the presence of air in the cabin.* The physiological risk is not minimal since the air cabin atmosphere could contaminate the suit loop.

5.2 Pad Access - Hatch Closed Regime (-90 < T < 0 Minutes)

This is the earliest time the cabin can be exposed to pure oxygen; however, the quick opening capability of the Unified Hatch results in essentially unimpeded egress and continued accessibility of pad personnel and facilities to provide emergency support. Due to hatch closure, the fire risk with air will increase somewhat; however, for oxygen, the increase is larger due to the change in composition. The physiological risk with air is unchanged and dependent on isolation of the suit loop from the nitrogen in the closed cabin; with oxygen the risk is reduced due to the removal of nitrogen from the cabin.

5.3 Constant Pressure Regime (0 < T < +50 Seconds)

The significant feature of this regime is the increase in the fire risk--for the rest of the mission--with both oxygen and air cabin atmospheres due to the loss of pad access at lift-off. The fire risk is also high because cabin pressure is high. The launch environment is active but only moderate and relatively constant while cabin atmosphere pressure remains constant at atmospheric levels.

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*Air will be the cabin atmosphere before hatch closure regardless of the decision to use air or oxygen on the pad.

The physiological risk increases at lift-off but is acceptable since both air and oxygen are viable for the stresses imposed on the crew by the launch environment (i.e., g-loads) in the nominal or abort profiles. The risk with air is still dependent on the possibility of suit loop contamination by nitrogen.

5.4 Maximum Launch Environment Regime (50 < T < 120 Seconds)

The fire risk in this regime is dependent on two additional factors--increasing environmental stresses and decreasing spacecraft atmosphere pressures. The launch environment is the most severe in this regime; maximum acoustic noise occurs about T+65 seconds (Mach 1), the vibration loading and aerodynamic pressure maximize at about T+85 seconds, and the longitudinal g-loads due to the decreasing space vehicle weight are increasing more rapidly. Since the spacecraft is subjected to maximum physical forces, the probability of activating potential ignition sources is increased; given ignition, higher convective forces increase the probable rate of fire propagation. Further, the resultant immobility and isolation of the crew hinder fire detection and control capabilities. The cabin atmosphere and suit loop pressures rapidly decrease from pad pressure to essentially flight pressures in this regime with two effects. During this pressure reduction, turbulence resulting from the outward flow of the cabin atmosphere may increase the rate of fire propagation. The reduction in pressure and oxygen content reduces the risk of ignition and rate of propagation.

The increase in ignition source hazard and in flammability due to environmental effects may--or may not--be offset by the reduction in ignition source hazard and flammability due to the pressure reduction. The current understanding of the basic mechanics does not permit much more than a subjective evaluation of these effects. Thus, the fire risk will still be significantly high and may be either more or less than that for 0 < T < 50 seconds. The eventual effect is a reduction in the fire risk due to the pressure decline to a value higher than but approaching the in-flight fire risk. In any event, the fire risk with oxygen is higher than with air.

The maximum launch environment increases the physiological risk to higher values in this regime; however, while the decrease in cabin pressure results in a nominally nonviable cabin atmosphere with air, the higher physiological risks with air are acceptable due to the short time of flight in the event of abort.

5.5 Maximum Launch Abort Environment Regime (T+120 Seconds to Insertion)

The factors that determine fire and physiological risks for the nominal mission in this regime are not greatly different from the in-flight environment --i.e., low g--except for $120 < T < 155$ seconds when nominal mission g-loads peak at 4.7 g. After T+155, they do not exceed 2.5 g. Vibration levels are reduced and cabin pressure is at essentially the flight value.

A significant physiological risk results from the magnitude (>>4g) and duration of the abort g-loads during reentry. Since aborts can occur due to failures in the primary atmosphere, the backup should be pure oxygen for these loads. This results in a higher physiological risk with air if the cabin is used as the backup; the risk with oxygen, however, is not negligible since arterial desaturation due to excessive g-loads is not eliminated with pure oxygen.

The fire risk of the nominal profile is only slightly higher than the in-flight risk--with oxygen of course higher than air.

5.6 In-flight

If the spacecraft is inserted into orbit with an air cabin atmosphere, then the physiological risk will be high until the cabin atmosphere is changed to pure oxygen. If the change involves complete depressurization then a further increase in the physiological risk results from complete reliance upon the pressure integrity of the space suit during this period. With oxygen in the cabin, the physiological risk after orbital insertion is acceptable.

The fire risk after insertion is reduced slightly since the launch environment is completed and is still higher with oxygen than with air. While it is difficult to compare fire risks--air and oxygen--at 5 psia and zero g with those for air at 14.7 psia and one g before hatch closure, it is assumed here that the in-flight risks must by definition be somewhat higher due to the inherent inaccessibility of the spacecraft in-flight.

5.7 Risks Summary

Regardless of cabin atmosphere composition, the overall fire risk increases significantly at lift-off due to increased environmental stresses, the continuance of high cabin pressures, and the elimination of crew egress and pad support; part of this risk (loss of egress and pad support) is incurred for the duration of the mission.

The time of maximum fire risk is somewhere after lift-off and prior to the time where abort entry loads become excessive but is not known precisely as it depends on the opposing effects of maximum launch environment and decreasing cabin pressures. This fire risk can be greatly reduced by using air in the cabin instead of pure oxygen; however air in the cabin results in an increase in physiological risk that extends beyond the period of maximum fire risk if the cabin atmosphere is the backup atmosphere. Air in the cabin also increases the risk of suit loop contamination with nitrogen.

6.0 OPTIONS AVAILABLE

The options to be considered in managing atmosphere dependent risks are:

1. Review the basic program requirement for backup capabilities with a view toward acceptance of the existing risks;

2. Make provisions for use of oxygen in the cabin during prelaunch including an accessible and viable backup atmosphere during launch.

3. Make provisions for use of air-on-the-pad including:

   (a) an accessible and viable backup atmosphere during launch,

   (b) cabin atmosphere exchange, and

   (c) other current air-on-the-pad program changes.

A change in the program requirements for backup capabilities is considered unacceptable for reasons of crew safety.

An accessible and viable backup atmosphere is the critical determinant since it is basic to the use of oxygen or air. Two alternatives are available: make the cabin physically accessible and viable to the crew or provide an alternate backup atmosphere independent of the cabin atmosphere* and therefore independent of an air-on-the-pad decision. Preferably, the backup atmosphere should also be independent of the suit loop atmosphere in order to provide the greatest possible backup capability. As it was noted earlier, the cabin and suit loop

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*An alternate backup atmosphere may be independent of both pressure and composition of cabin atmosphere or independent of composition only.

atmospheres are not completely independent and, as a result, failures affecting common parts of both the suit loop and cabin atmosphere systems could be more critical.*

Accessibility of the cabin atmosphere is dependent on three constraints: (1) feasibility of space suit modification, (2) acceptability of the cabin acoustical environment, and (3) the feasibility of enriching the cabin to the required composition if air is used. The definition of the functional capabilities required for cabin accessibility and the feasibility of changing the design of the Apollo space suit were not a part of the studies supporting this review. However, the schedule impact alone would be significant considering the current suit procurement schedules.

The cabin acoustical environment is significantly worse than the internal suit environment due to the isolation afforded by the helmet. As a result, the cabin acoustical environment may not be acceptable in a contingency situation since crew-to-crew communications and crew-to-ground communications could be essential to successful post contingency crew operations and crew status assessment by the ground.

The feasibility of enriching an air cabin atmosphere can be evaluated using Reference 4 which describes the basic design parameters of an enrichment system. Briefly, for a 95% oxygen cabin atmosphere it shows:

(a) Current gaseous oxygen storage capability is inadequate for enrichment;

(b) The minimum requirement for oxygen is about eight pounds for enrichment with complete cabin depressurization;

(c) Enrichment by purging (i.e., without depressurization) at $T > 120$ seconds requires 27 pounds and about three minutes at 0.15 lbs/sec;**

(d) Enrichment by purging starting at T-0 requires 35 pounds and about four minutes at 0.15 lbs/sec.

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*For example, failures resulting in a toxic atmosphere (e.g., atmosphere contamination due to structural failure of a lithium hydroxide cannister) would probably contaminate both the suit loop and cabin atmospheres.

**The current emergency repressurization rate in the CM is limited by one emergency pressure regulator to about 0.7 lb/min or 0.01 lb/sec and is available only from the gaseous oxygen tanks. Oxygen from the cryogenic oxygen tanks is limited by flow restrictors to about 0.002 lb/sec.

Thus, enrichment to 95% oxygen before T+120 seconds requires either partial enrichment on the pad or very high flow rates after launch to reduce the time and total oxygen required. In addition, a minimum of about 30 pounds of spacecraft oxygen is required for purge modes. Finally, enrichment before T+120 seconds is not consistent with reduction of the fire risk before T+120 seconds. Therefore, the feasibility of space suit modification and cabin enrichment and the acceptability of the cabin accoustical environment mitigate against the provision of a viable and accessible cabin atmosphere as a launch phase backup atmosphere.

The remaining alternative of providing the crew with an alternate--and preferably independent--backup atmosphere during the launch phase is discussed in Reference 5.* It was concluded that one of the contingencies an Alternate Oxygen System (AOS) could support is low partial pressure of oxygen (air) in the cabin during the launch phase.** The design constraints for this capability were defined; briefly, these are: (1) rapid operation, (2) operable under g-loads, (3) usable with suits on, and (4) capable of short term gaseous oxygen supply. The principal design change required in the currently planned "oxygen mask" is a direct connection from the gaseous oxygen supply to the existing unused Portable Life Support System umbilical connection on the space suit; a direct line to the helmet could also be used.

If an air cabin atmosphere is not made viable during the launch phase, then at some later time in the mission the cabin must be converted to an oxygen atmosphere. Reference 6 reviews the existing hardware capability of the spacecraft to change an air cabin atmosphere to oxygen. While there are a number of variables which affect the process, Reference 6 concludes that an 85% oxygen atmosphere can be realized before the earliest second Atlantic injection opportunity (T+95 minutes). This requires partial cabin depressurization (to about 2 psia) and the use of about half of the gaseous oxygen supplies in the Command Module supplemented by oxygen from the cryogenic supplies in the Service Module.

To summarize, regardless of its composition, accessibility of the cabin atmosphere for use as a backup atmosphere is inhibited during the S-IC portion of the launch phase by the nominal launch environment, the abort environment, and current space suit design; further, accessibility may be marginal throughout the

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*Possible requirements for an Alternate Oxygen System were identified for the launch phase and for other phases of the mission.

**It was also noted that an AOS could cope with toxic failures resulting in contamination of both the cabin and suit loop atmospheres.

remainder of the launch phase. Given accessibility, air in the cabin is not acceptable for T $\geq$ 120 seconds without enrichment to pure oxygen. Enrichment is not considered appropriate since it requires adding oxygen in the cabin when fire risk is at or near its maximum. Further, use of the cabin entails a degraded--and possibly unacceptable--acoustical environment. A viable and accessible backup atmosphere can be provided consistent with the requirement for an air-on-the-pad capability by supplying an alternate backup atmosphere directly to the suited crew. In addition, such an alternate atmosphere would support a complete depressurization of the cabin for cabin atmosphere exchange.

7.0 SUMMARY AND RECOMMENDATIONS

If the current Apollo Program crew safety requirements for primary and backup capabilities are valid, a review of the implications of using oxygen or air as a cabin pressurant in Apollo launch operations has shown:

1. Cabin Atmosphere Accessibility - The bubble helmet of the Apollo space suit and the launch environments may preclude accessibility to the cabin atmosphere for use as a backup atmosphere during S-IC burn--and possibly for all of the launch phase--regardless of the use of air-on-the-pad.

2. Alternate Backup Atmosphere - An alternate oxygen supply connected directly to the suited crew is required to assure accessibility to a backup atmosphere regardless of the use of air-on-the-pad. It may also be useful in the exchange of an air cabin atmosphere to an oxygen atmosphere. (See 7 below.)

3. Pure Oxygen Backup - The magnitude and duration of acceleration loads in the launch phase, both nominal and abort, support a requirement for a pure oxygen backup atmosphere no later than two minutes after lift-off.

4. Acceleration Environment Physiological Data - Data is needed relating required crew performance capabilities and Apollo acceleration environments --both nominal and abort --to atmospheric requirements for the launch phase.

5. Maximum Fire Risk - While the results of the material selection program are needed to assess actual fire risk, a high fire risk with oxygen or air occurs after launch and sometime during the S-IC part of the launch phase. The use of air-on-the-pad to reduce this fire risk

would cause an unacceptable increase in crew risk at about T+120 seconds if the cabin atmosphere is the backup atmosphere. An alternate oxygen supply (item 2 above) would eliminate this consideration.

6. Prelaunch Cabin Enrichment - Prelaunch enrichment of an air cabin atmosphere for (a) use as a backup during launch or (b) for reduction in the requirement for spacecraft oxygen for cabin atmosphere exchange is inconsistent with the provision of an air-on-the-pad capability for the management of fire risk.

7. Additional Gaseous Oxygen - Air-on-the-pad requires an in-flight change of the cabin atmosphere to an oxygen atmosphere. If this exchange must be accomplished in less than about an hour, additional gaseous oxygen supplies may be required. Eight pounds of oxygen are required for cabin exchange with complete depressurization and at least 27 pounds without depressurization to realize a 95% oxygen atmosphere. If cryogenic oxygen supplies are used with a part of existing gaseous supplies, an 85% oxygen atmosphere can be realized before the earliest second orbit injection opportunity with only partial cabin depressurization. An alternate oxygen supply (item 2 above) could serve as the backup atmosphere during partial or complete cabin depressurization either in orbit or during the latter part of the launch phase.

To provide both oxygen and air cabin pressurant capabilities and to assure an accessible backup atmosphere in the launch phase, it is recommended that:

1. An alternate oxygen supply be implemented to provide pure oxygen directly to suited crewmen independent of the suit loop during launch.

2. Additional gaseous oxygen supplies should be added to the CSM if a rapid conversion to a high purity (>95%) oxygen cabin atmosphere without depressurizing the cabin is required.

3. Data be procured to better define the physiological effects of Apollo g-load environments -- both nominal and abort -- on atmosphere requirements in the launch phase. Consideration should also be given to the similar environments occuring during reentry at the end of the Apollo mission.

4. The materials selection program be examined to provide assurance that sufficient data will be provided on the fire hazards between 50 and 155 seconds after launch when maximum launch environments exist and when cabin atmosphere pressures are falling to flight levels resulting in cabin atmosphere turbulence.

Finally, it is noted that the requirement for a viable cabin backup atmosphere is reduced and perhaps eliminated by the implementation of an Alternate Oxygen Supply available to the crew at all times for use as a backup atmosphere during prelaunch and launch. This permits added flexibility in the reduction of fire risk. For example, an inert gas in the cabin would result in virtually a nonflammable spacecraft and reduced requirements for quick egress on the pad due to fire risk.

P. F. Sennewald

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Attachments
References
Figures 1-3

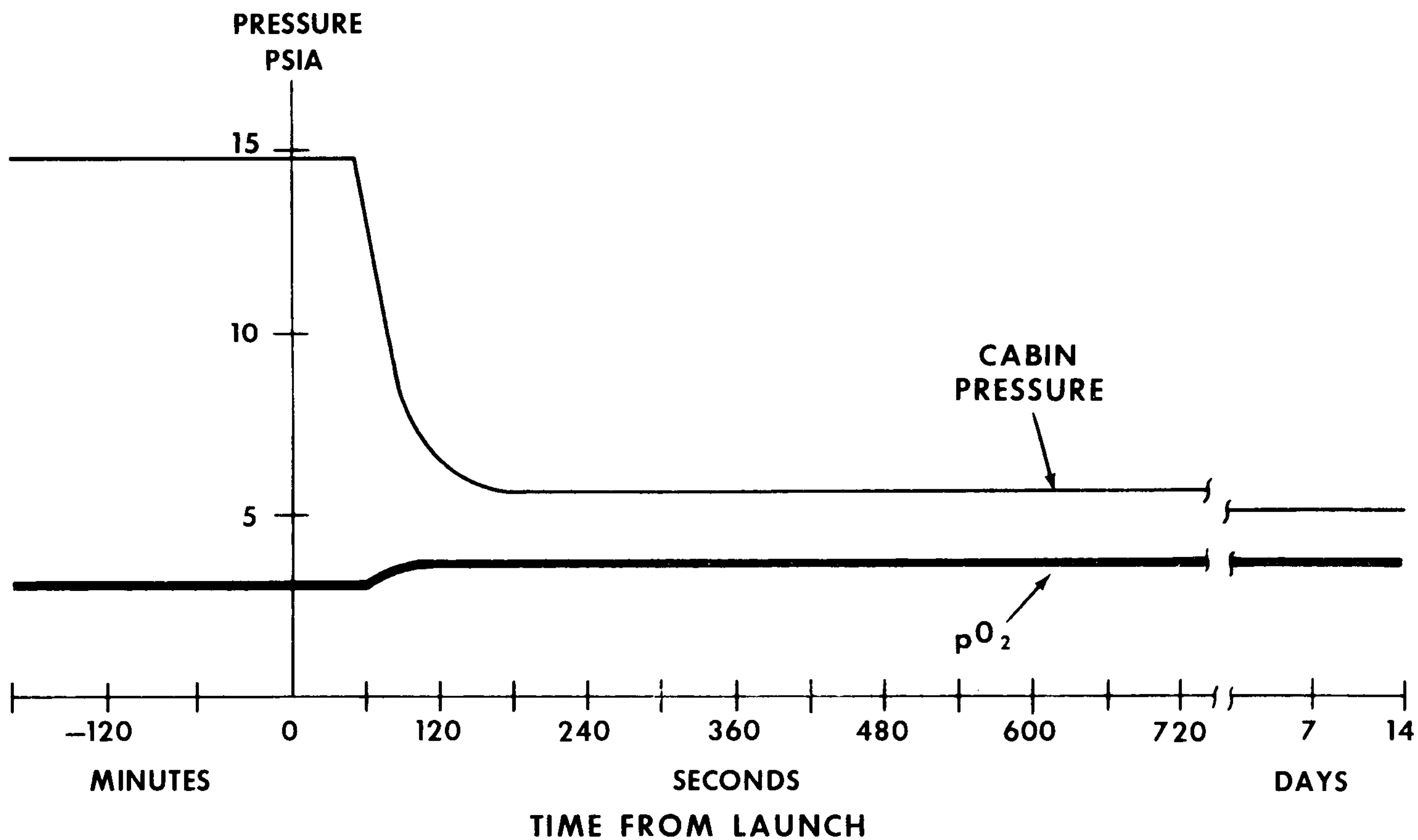

FIGURE I - SPACECRAFT ATMOSPHERE MINIMUM PARTIAL PRESSURE OF OXYGEN (pO_2)
FOR SEA LEVEL EQUIVALENT PERFORMANCE

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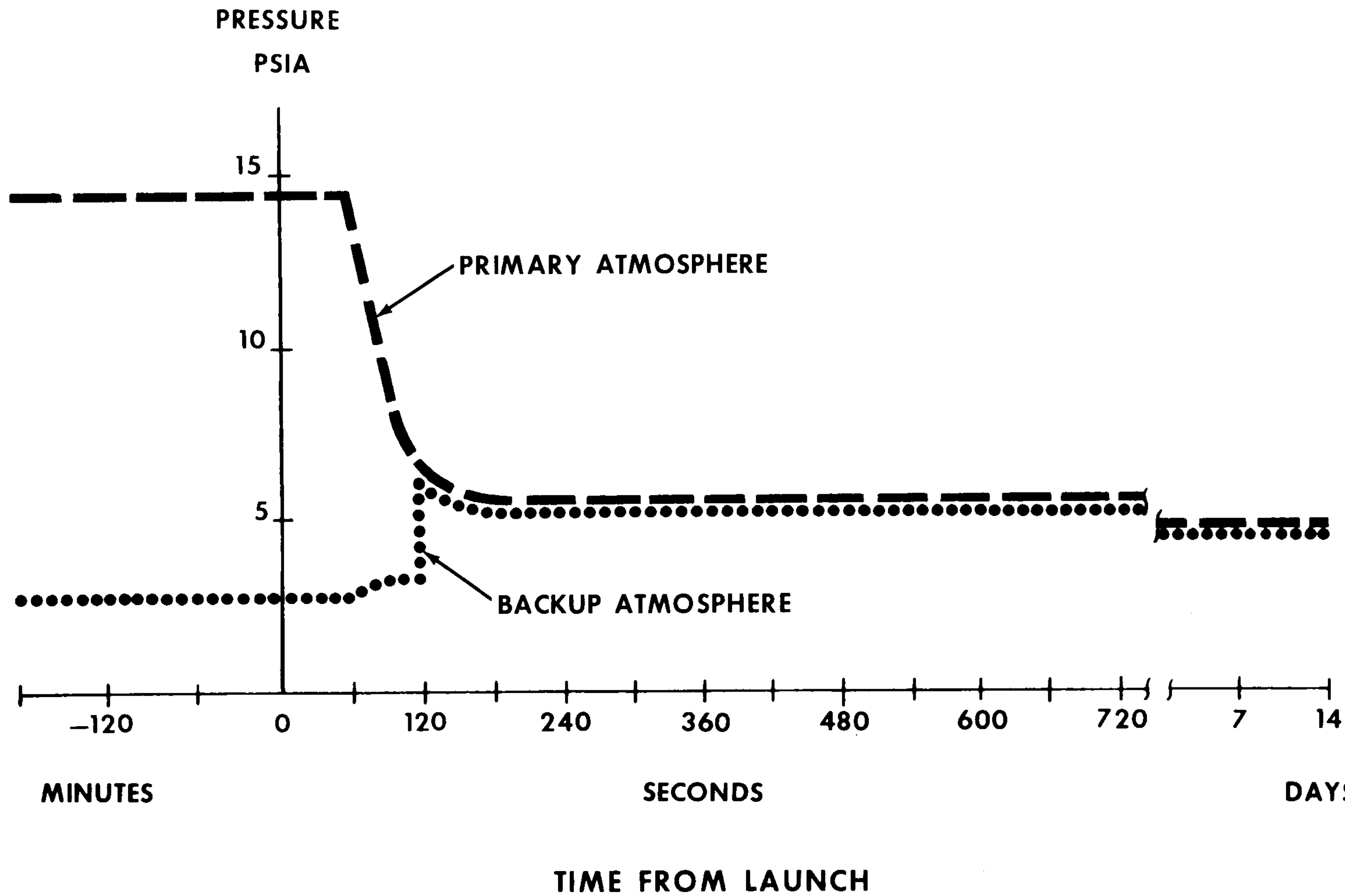

FIGURE 2 - REQUIREMENTS FOR COMPOSITION AND PRESSURE OF SPACECRAFT ATMOSPHERES

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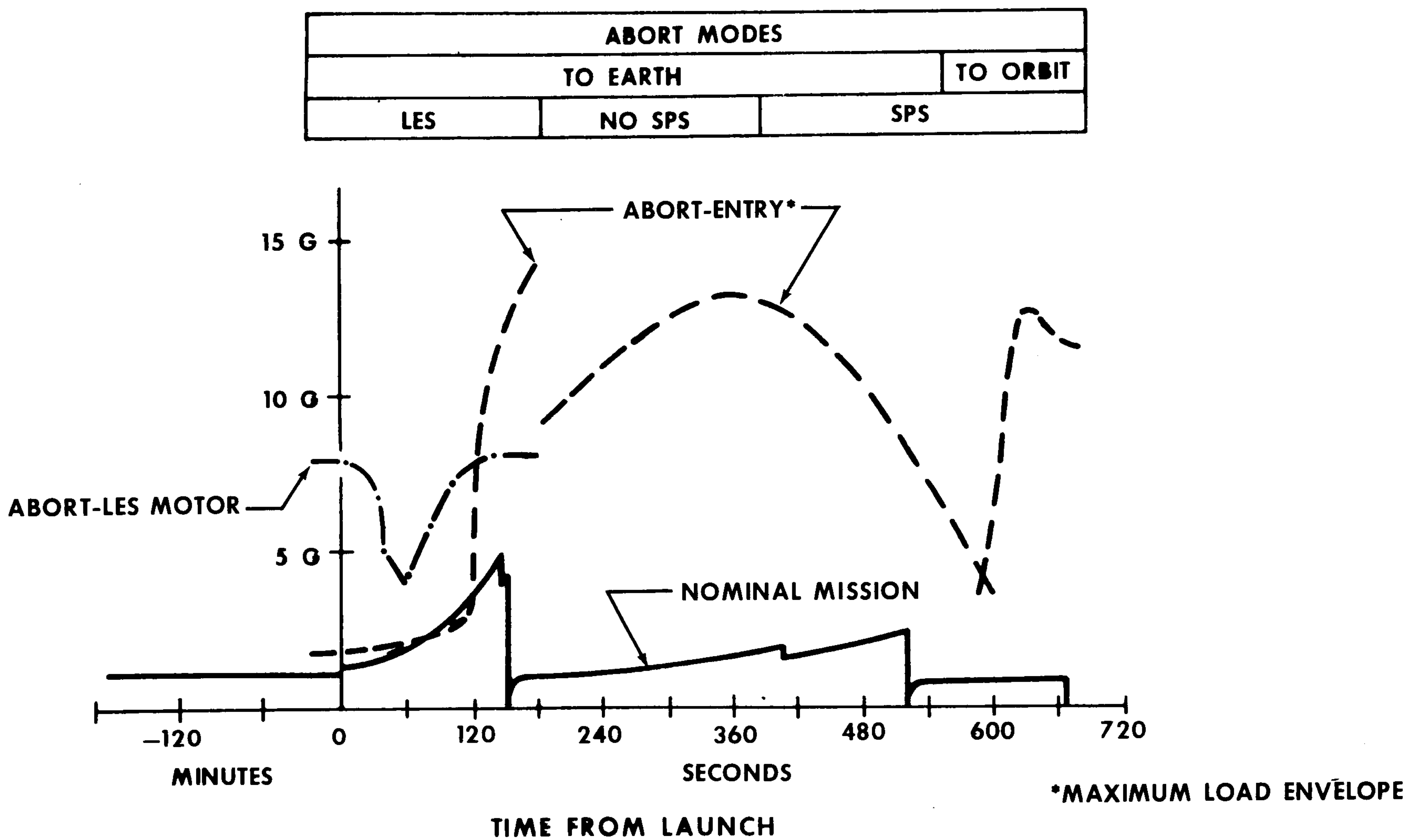

FIGURE 3 - AXIAL ACCELERATION LOADS DURING SATURN V LAUNCH PROFILES

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